

Determination of Load Carrying Capacity of Clay Bricks Reinforced With Straw

Samson Olalekan Odeyemi¹, Mutiu Adelodun Akinpelu¹, Olumoyewa Dotun Atoyebi² and Rukayah Titilope Yahaya¹

¹ Department of Civil Engineering, Kwara State University, Malete, Nigeria

² Department of Civil Engineering Department, Landmark University, Omu-Aran, Nigeria

*Corresponding E-mail: samson.odeyemi@kwasu.edu.ng

Received 13 July 2017; Revised 30 November 2017; Accepted 21 December 2017

Abstract

Sandcrete block is a dominant material for wall construction but it is often characterized with high cost and low strength property. This has necessitated the need to source for new materials within our environment. Clay is a natural material that is widely available in many countries of the world and it has the potential to establish better strength property than sandcrete blocks when mixed with straw. The straw serves as reinforcement that increases its compressive strength. The results obtained from this research shows that with the addition of straw (0.0025%, 0.005%, 0.0075% and 0.01%) at water-clay mixing ratio of 0.15, the compressive strength of the clay brick increased up to 148% of the strength of the clay without straw. The Scanning Electron Micrograph (SEM) results shows a strong adhesion between brick and straw fiber without any sign of brick saturation. This reveals that the addition of straw increased the compressive strength of the clay brick.

Keywords: *Bricks, Straw, Clay, Compressive strength, Scanning Electron Micrograph*

1.0 Introduction

Clay brick is the oldest building material known. It is widely available in many countries [1]. It is broadly applied in both load bearing and non-load bearing structures due to its durability and aesthetic properties [2]. Factors like the mineralogical compositions of the clay, the production process and the firing temperature has a lot of influence on clay properties [3].

The Nigeria Industrial Standard [4] defined the compressive strength of block as “the load at failure in compression divided by the apparent bearing area of the block”. The Standard specified that 2.5 N/mm² should be the minimum compressive strength for individual load bearing blocks and 3.45 N/mm² shall be the minimum average compressive strength of five blocks. This is in agreement with various national standard specifications for concrete blocks [5], [6], and [7].

The low strength properties of commercially available sandcrete blocks necessitate the need for alternative low cost walling material for construction and clay bricks with straw promises to be a solution. The determination of their compressive strength will help to determine their effectiveness in load bearing. Thus, this research aims to determine the load carrying capacity of clay brick incorporated with straw.

2.0 Literature Review

Clay is a natural earthy material, which with acceptable water content stays in plastic state when wet, harden nature when dry and increases in strength like a permanent solid when under heat intensively. It is a fine-grained material that consist of aluminium hydrated silicates [8]. Clays can be seen in different colours like dull grey, white, brown and deep orange-red. Water content of clay makes it to be plastic, processes of drying and firing makes it to be hard, brittle and non-plastic. Clays are distinguished from other fine-grained soils by differences in size and

mineralogy [9]. Clays and its minerals are very useful as industrial minerals; hundreds of industrial applications are credited to their use owing to it been available abundantly and less expensive [10]. Clays are also used in engineering and construction applications, agricultural applications, geology, food processing, pharmaceuticals, environmental remediation and many other industrial applications [11].

Clay brick masonry is one of the oldest and most durable construction techniques used by man [12]. Brick, which is mostly used in the building industry, is gotten through a firing process (900-1200°C) of clay which has been cut into rectangular blocks standard sizes [13]. Generally, a good brick must be hard, well burnt, uniform throughout, sound in texture and colour, and should not break easily when stuck against another brick or dropped from a height of about one meter [14]. In using burnt clay bricks for construction, certain desirable properties should be achieved. Among these desirable properties are compressive strength, density, thermal stability, porosity, sound insulation, fire resistance and durability.

Straw is the springy tubular stalk of grasses that contains cellulose, hemicellulose, lignins and silica. Many clay products require the addition of other materials to add strength and durability. Straw is an indispensable material used to produce bricks; the straw holds the clay together, keeps the bricks from experiencing cracks and going out of shape, and facilitates drying. Moses and Aaron, in the book of Exodus of the Bible, demanded for the release of the Israelites from Pharaoh. He refused and ordered his supervisors not to allow any of the Israelites to mix straw with the clay to be produced and it must not reduce the expected quantity to be produced per day. The Israelites grumbled to Moses and Aaron that they have now made things worse for them. This explained how important the straw was in clay [15].

Sustainability is a major focus in international housing development strategies. Cellulous non-wood fibrous materials, such as straw is one of the most abandoned materials as they are often burnt in agricultural fields. Instead of burning the straw, recycling it will not only form a sustainable low-cost building material, but will also reduce air pollution [16].

Water is an important element in construction. Some of its usage includes mortar preparation, cement concrete production and curing. Its quality and quantity determines the strength of cement concrete and mortar in construction. Quantity of water in cement paste determines the properties of the cement paste, Stronger and durable concrete is achieved with cement paste with less water while a free flowing concrete with higher slump is as a result of more water in the cement paste. The concrete setting time can also be affected by the level of impurities in the water. Examples of such impurities are sewage, organic matter, alkalis, silt and acid. The use of sea water should be avoided where concrete with a good appearance is required [17].

3.0 Methodology

The material constituents, their mix, manufacturing process, curing are paramount important factors that determine the strength of solid clay bricks.

The clay sample used in this research was dug from Wara village located on latitude 8°28'39.77"N and longitude 4°29'15.82"E, near Lubcon Oil Industries, Ilorin, Kwara State, Nigeria. It was kept safe in clean sack bags properly tied with rope and dried in the soil laboratory at the Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria.

Portable water, which was free from suspended particles, salts and oil contamination was used throughout this research.

Horse grass specifically tall fescue (*Festuca arundinacea*) was used as the straw to reinforce the clay brick due to its availability at the time of carrying out this research. It is a cool-season perennial bunch grass. This material was sourced within the University of Ilorin, Kwara State, Nigeria.

The clay samples collected were taken out of the bags, slightly pulverized with minimal pressure to break up the lumps which had formed during storage and spread out on jute bags at the laboratory to facilitate quick air drying. Liquid limit and plastic limit tests were used to determine the Atterberg limits.

The liquid limit is the moisture content at which a soil sample begins to flow to close a groove of standard dimension for a distance of 25mm made in the soil paste after the application of 25 blows in a liquid limit apparatus. In carrying out the liquid limit test, the following apparatus were used: Casagrande's apparatus; grooving tool; weighing balance; electric oven; Sieve; containers and Spatula.

The following steps were followed for the liquid limit test:

- i. 120gm of clay passing through sieve size 0.75mm was put in a container.
- ii. Water was added to the clay sample and a uniform paste was formed through proper stirring using a spatula.
- iii. A portion of the paste formed was placed in Casagrande apparatus cup and a smoothened surface was created with a spatula.
- iv. A groove was made in the soil paste by the means of grooving tool.
- v. The handle of the Casagrande apparatus was turned at a rate of about 2 rev/sec until the two parts of soil sample came into contact along a distance of 12.5mm.
- vi. The number of blows used for the two soil samples to come in contact was noted.
- vii. Moisture content was determined on a sample of soil paste taken from the Casagrande apparatus cup.
- viii. Procedure described in step i to step vii. was repeated by increasing the soil sample water content for four times.
- ix. A graph of Number of blows on log scale was plotted against known Moisture content on ordinary scale.
- x. The moisture content corresponding to 25 blows from the graph gave the liquid limit of the soil.

Plastic limit is the minimum water content at which a soil thread of 3.2mm diameter starts crumbling. The plastic limit values are used to determine the toughness index, flow index and plasticity index of soil. The following apparatus were used in determining the plastic limit of the soil: Sieve; glass plate; weighing balance; china dish; electric oven; and spatula.

The following steps were followed for the plastic limit test:

- i. 50gm of dry clay passing sieve 0.75mm was put in a dish;
- ii. Water was added to the soil and stirred properly by the means of a spatula;

- iii. 10gm of soil paste was taken and rolled with into a small ball;
- iv. The ball was placed on a glass plate and rolled to remove moisture and for soil thread forming;
- v. The pieces of crumbled soil at 3.1mm diameter was collected and placed in a container for moisture content determination;
- vi. The procedure described in step i to step iv was repeated four times;
- vii. The average of the four readings was taken as the plastic limit for the soil.

Plasticity index (PI) was calculated from the liquid and plastic limits using Equation 1.

$$PI = LL - PL \quad (1)$$

Where: LL is the Liquid limit and PL is the Plastic limit

In this study, the manual method of mixing was used for the solid clay bricks. The clay and straw were mixed in a dry form and water was added in spray form in moderate proportions to avoid excess water which could cause shrinkage and distortion of block on drying. The weight of the brick without straw was 4kg. Water:Clay mixing ratio of 0.15 was adopted in this research. 10g, 20g, 30g and 40g of straw were added to the clay bricks respectively. Brick moulding machine was used in the moulding and compacting of the clay brick with straw. The size of the moulds used were 230mm x 110mm x 95mm. Drying was carried out to remove moisture and allow proper hydration and hardening of the solid clay bricks. Sun drying method was adopted for the bricks for a period of 21 days after which they were tested for their compressive strengths. The Compressive strength tests were carried out using a Testometric material testing machine at the Mechanical Laboratory of the University of Ilorin, Kwara State, Nigeria. 15 brick samples were investigated for their strengths. Figure 1 shows a sample brick in the Testometric machine.



Figure 1: Brick in the Testometric machine

4.0 Results and discussions

In this section the Atterberg's limit obtained from the liquid and plastic tests, and the compressive strength of the clay bricks with straw are discussed.

4.1 Atterberg limit

Table 1 contains the liquid test results while Table 2 contains the plastic limit test result. Figure 3 shows a plot of the Number of blows against the Moisture content for the soil sample used in this research. Whitlow [18] reported that liquid limit less than 35% indicates low plasticity, between 35 and 50% intermediate plasticity, between 50% and 70% high plasticity and between 70 and 90% very high plasticity and greater than 90% extremely high plasticity. The liquid limit obtained from Figure 2 is 35% indicating that the soil has intermediate plasticity since the liquid limit falls between 35 and 50%.

Table 1: Liquid limit

Can No.	X	P9	M7	11	D5
Weight of wet soil +can (g)	41	37	36	35	32
Weight of dry soil + can (g)	34	32	31	30	29
Weight of can (g)	18	18	18	17	19
Weight of dry soil	16	14	13	13	10
Weight of wet soil (g)	23	19	18	18	13
Weight moisture (g)	7	5	5	5	3
Water content (%)	43.75	35.71	38.46	38.46	30
Number of blows	11	14	16	20	32

Table 2: Plastic limit

Can No.	B4	E	H2	13
Weight of Wet soil +Can (g)	24	20	24	20
Weight of dry soil + can (g)	24	19	23	19
Weight can (g)	19	14	17	13
Weight of dry soil	5	5	6	6
Weight moisture (g)	5	6	7	7
Water content (%)	14.29	33.33	20	33.33

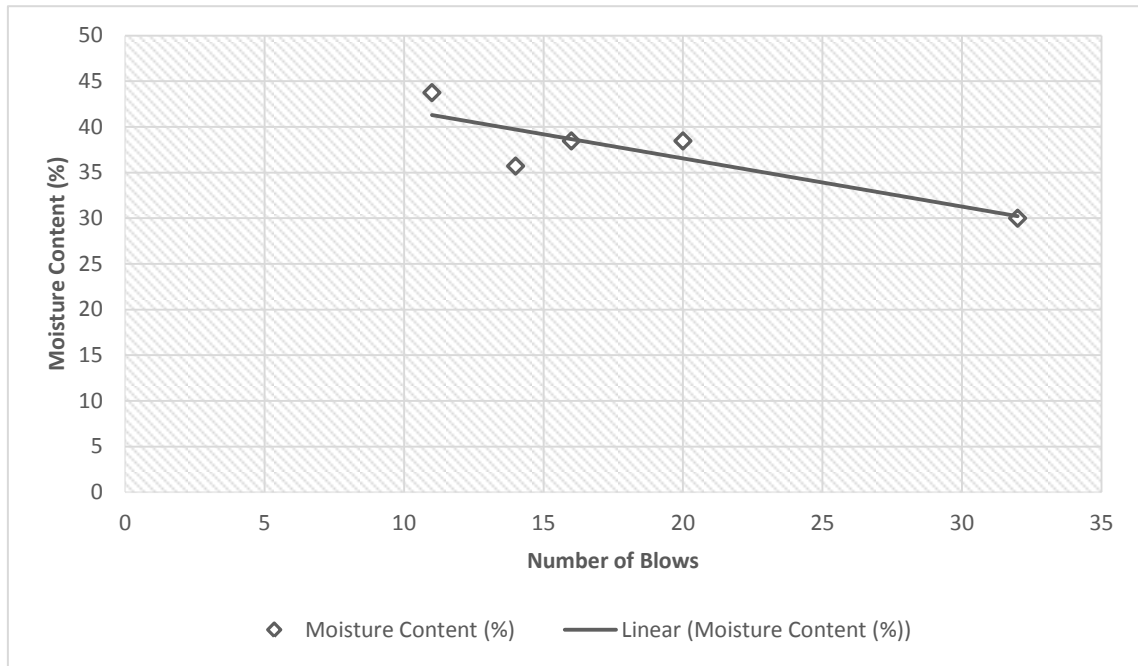


Figure 2: Liquid limit graph

4.2 Compressive strength test

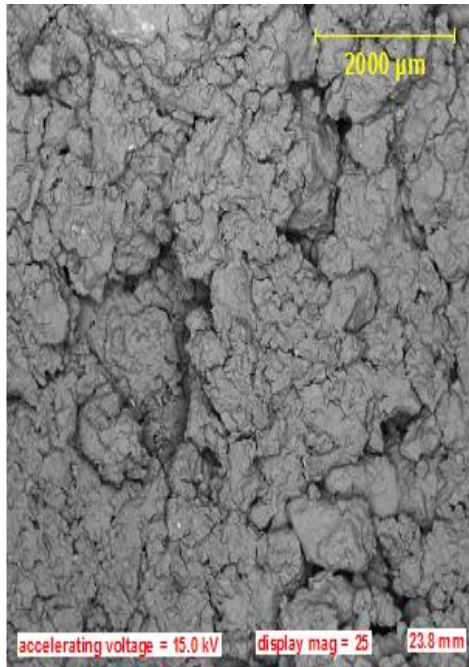
The results obtained after carrying out a compressive test on the bricks is shown in Table 3. The result shows that with the addition of straw, the compressive strength of the clay brick continued to increase from 0.748N/mm^2 for clay brick without straw to 1.859N/mm^2 for clay brick with 0.01% straw. This shows that the addition of straw increased the compressive strength of the clay bricks.

Table 3: Compressive strength of brick samples

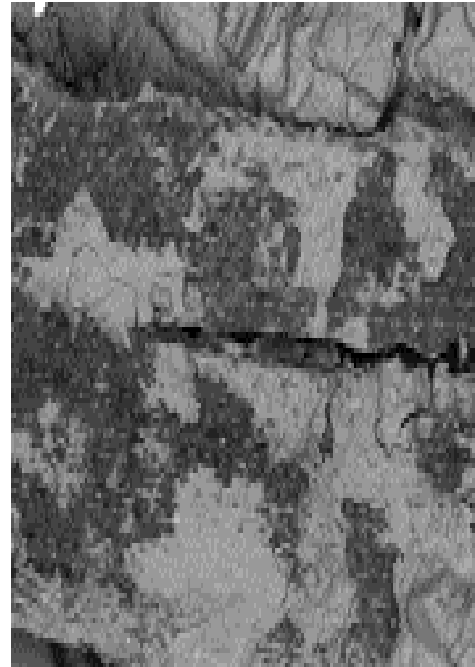
Sample type	Compressive stress (N/mm^2)
Brick without straw (control)	0.748
Brick with 10g (0.0025%) of straw	1.094
Brick with 20g (0.005%) of straw	1.403
Brick with 30g (0.0075%) of straw	1.45
Brick with 40g (0.01%) of straw	1.859

4.3 Scanning Electron Micrograph (SEM) results of bricks with varying percentages of straw

Figure 3(a)-(e) present the scanning electron micrographs of a brick and the straw reinforced brick composites achieved at different percentage weight of fibre additions.



(a) Brick without straw



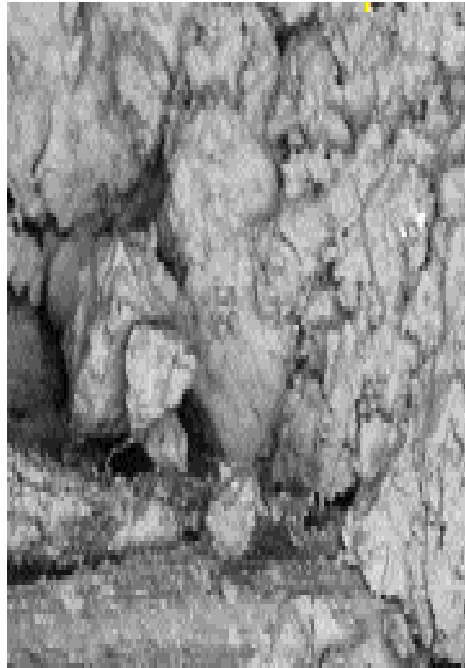
(b) Brick with 0.0025% straw



(c) Brick with 0.005% straw



(d) Brick with 0.0075% straw



(e) Brick without 0.01% straw

A number of brick platelets assuming three dimensional skeletal networks produced from interactions of many tetrahedral shapes found in silicate compounds which are common to all naturally occurring ceramics clay such as bricks. The tetrahedral interactions are possible because of plasticity of the clay. When water is added there is formation of ionic bonds from reactions between aluminium ions from clay and hydroxide ions from water. During anions and cations interactions, formations of many ceramic molecules as shown in Figure 3(a) occurred. Structural modifications observed in Figure 3(b)-(e) are attributed to additions of straw fibers at different percentage weight of fibre additions which are responsible for their increased packing density as noticed from Figure 3(b)-(e). Essence of the straw fibers embedded within the brick matrix are to act as load bearers which will enhance the strength of the brick/straw fiber composites. The degree of enhancement depends on percentage weight of the added fibers, the interfacial bonding between the fibers and the brick matrix and saturation of the matrix with the fibers. A good interaction is very apparent in Figure 3(b)-(e), which can be described as strong adhesion between brick and straw fiber without any sign of brick saturation. With this structural integrity, an enhancement in the mechanical properties is expected of the brick/straw fiber composites.

5.0 Conclusion

The following were established in this research:

1. The addition of straw reinforces the strength of clay bricks by increasing the compressive strength of the bricks;
2. The SEM results shows a strong adhesion between brick and straw fiber without any sign of brick saturation;
3. There is an enhancement in the mechanical properties of the brick/straw fiber composites.

References

- [1] M. F. Francisco, "Ancient Clay Bricks: Manufacture and Properties," *Materials Technologies and Practice in Historic Heritage Structures*, 2010.
- [2] A. W. Hendry, *Reinforced and Prestressed Concrete*. New York: John Wiley & Sons, Inc., 1991.
- [3] J. Izwanbin, "The influence of rice husk as partial replacement material in fired-clay brick," Ph.D, Civil Engineering, Universiti Sains Malaysia, 2010.
- [4] NIS 87:2000, "Specification for sandcrete Blocks," ed: Standard Organization of Nigeria, Lagos, Nigeria.
- [5] BS 2028, "Precast Concrete Blocks," ed: British Standard Institution. Canada West Foundation, 1978.
- [6] ASTM Standard C145, "Standard Specification for solid Load-Bearing Concrete Masonry Unit," ed, 1975.
- [7] ASTM Standard C90, "Standard Specification for hollow Load-Bearing Concrete Masonry Unit," ed, 1975.
- [8] N. Hendrik, "Clay Materials for Self-Reliant Potter," *Clay Science*, vol. 10, pp. 1-31, 1997.
- [9] S. Guggenheim and R. T. Martin, "Definition of clay and clay mineral," Joint report of the AIPEA nomenclature and CMS nomenclature committees 1995.
- [10] I. Suryadi, E. S. Felycia, and A. Aning, *Natural Clay Minerals as Environmental Cleaning Agents*, 2015.
- [11] H. H. Murray, *Applied Clay Mineralogy: Occurrences, Processing and Application of Kaolins, Bentonites, Palygorskite-Sepiolite, and Common Clays*: Elsevier, 2007.
- [12] B. D. Maria, P. Richard, and T. Akos, "Materials, Technologies and Practice in Historic Heritage Structures," ed: Springer Science and Business Media, 2009, p. 371.
- [13] P. Egbert, "Status and development issues of the brick industry in Asia," Food and Agriculture Organization, Bangkok, Thailand 1993.
- [14] A. A. Hammond, "Small and Medium Scale Brick and Tile Production in Ghana," 1997.
- [15] F. Ben. (2013, 7th July). *Making Bricks without straw: Moses, Covey, and Franklin on the character development*. Available: <http://cdn1-b.examiner.com/article/making-bricks-without-straw-moses-covey-and-franklin-on-character-development>
- [16] A. Mansour, J. Srebric, and B. J. Burley, "Development of straw-cement composite sustainable building material for low-cost housing in Egypt," *Journal of Applied Sciences Research*, vol. 3, pp. 1571-1580, 2007.
- [17] S. McFarlane, and Nilsen, E., "On Tap: Urban Water Issues in Canada Discussion Paper," Canada West Foundation, Calgary, Alberta, Canada 2003.
- [18] R. Whitlow, *Basic Soil Mechanics*, 4 ed. Edinburgh Gate Hallow: Pearson Education Ltd 2001.